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# Optical Vortex Metrology for Non-Destructive Testing

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Optical vortices or phase singularities in optical fields have been known for a long time, and their basic properties have been studied extensively since the seminal work by Nye and Berry in the early 1970s. Recently, phase singularities have come to attract new attentions for different reasons in the fields of applications such as optical metrology and photon manipulation. Because of their orbital photon angular momentum, optical vortices have proved themselves a useful means for optical trapping and manipulation of atoms and micro particles. On the contrary, phase singularities have been regarded as a nuisance by researchers in optical interferometry and profilometry, because the phase singularities hinder unique phase unwrapping of the measured phase values, which are usually wrapped into the range $[-\pi,\pi)$. Therefore, main efforts in optical metrology have been concentrated on how to get rid of the effect of phase singularities. A typical example is the phase unwrapping algorithm that directly kills out all phase singularities by superposing vortex fields with the phase singularities of opposite sign [1]. A question then naturally arises "Can phase singularities also prove themselves to be useful in optical metrology?"

The purpose of this talk is to give an answer to this question by introducing a new technique called optical vortex metrology, that makes use of the phase singularities in the pseudophase of the complex signal obtained from the Riesz transform or the Laguerre-Gauss transform of speckle patterns. Although this complex representation of real-valued speckle patterns does not introduce new information, it effectively exploits the existing information in such a manner that the newly introduced pseudoamplitude and pseudophase associated with the complex signal provide a powerful means for analyzing, processing and understanding the available information from the recorded speckle pattern. Furthermore, because the pseudophase can be detected without recourse to interferometry and the principle is based on tracing individual phase singularities as displacement markers, the proposed technique has the versatility that expands applications beyond those known for conventional correlation-based laser speckle metrology. Here, we will review the principle and demonstrate how effective use can be made of optical vortices or phase singularities for displacement [2-3], flow measurements [4] and biological kinematic analysis [5].

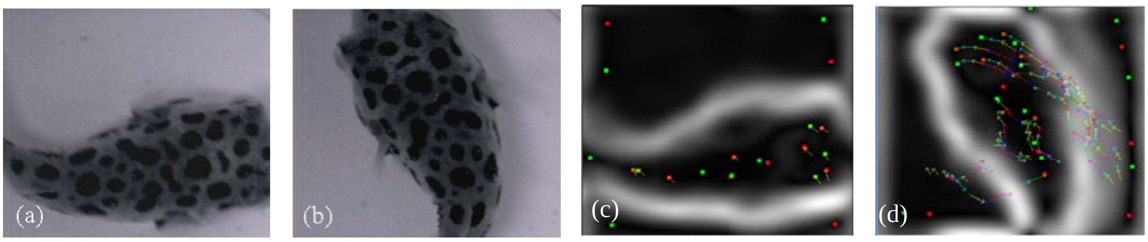


**Fig. 1** Recorded images for the swimming fugu at different instants of time and the corresponding trajectory of phase singularities; (a) and (c) are recorded at t=0.70 seconds; (b) and (d) at t=3.33 seconds.

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